WEST VIRGINIA UNIVERSITY
AGRICULTURAL EXPERIMENT STATION
MORGANTOWN, W. VA.

BULLETIN 99. FEBRUARY 1, 1906.

Experiments with Fertilizers

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EXPERIMENTS WITH FERTILIZERS.

A fertile soil is one in which the various elements of plant food are present in sufficient and properly proportioned quantities, and in forms which are both acceptable and available, and which moreover possesses a mechanical condition suitable for plant growth.

Unfortunately many soils are not fertile. They are either poor by nature or have been impoverished by improper management. The result in either case is the same. The crops are too small. How are the yields to be increased? Farmers in the Eastern States are relying largely upon the use of commercial fertilizers for this purpose. In West Virginia alone the value of the commercial fertilizer used amounts to about a million dollars annually, and if this large sum of money is to be spent each year by the farmers of this State for the purpose of securing better crops it is quite needless to say that these fertilizers should be used so as to produce the utmost possible increase in the yields of the crops for which they are applied. The experiments described in this bulletin have been performed so as to throw some light on this subject.

As soils differ remarkably in respect to their fertilizer requirements it is fortunate that the soil at the Experiment Station farm, where these experiments have been performed, is typical of a large part of the upland soil of the State. A description of the soil together with a table showing its chemical composition and mechanical condition follows:

The soil of the Experiment Station farm has been formed almost entirely through the decomposition and disintegration of the strata of rocks which, in this section, form the protective covering of the Pittsburg vein of coal. It is consequently a lightish soil, of a sandy texture, easily tilled, but which dries out too rapidly in summer. The original timber consisted of oaks, poplars, and chestnuts, together with an occasional locust, maple and beech.

The average composition of this soil as shown by a large number of analysis, is as follows:

SOIL FROM STATION FARM.

Figures represent the average of results from forty samples, surface and sub soil.

Chemical Analysis.	Surface.	Sub.
Insoluble matter	%86.25	86.14
Soluble silica	" 5.52	6.53
Potash	" 0.21	0.27
Soda	" 0.34	0.33
Lime	" 0.21	0.16
Magnesia	" 0.34	0.38
Manganese oxide	" 0.09	0.05
Ferric oxide	" 2.88	3.26
Alumina	" 4.30	5.37
Phosphorus pentoxide	" 0.10	0.10
Sulphur trioxide	" 0.04	0.04
Volatile matter	" 4.85	3.55
Nitrogen	" .09	.04
Humus	" 1.06	0.68

Mechanical Analysis. Particles %	Surface	Sub.
Greater than		
2. m.m.	2.35	2.71
1. m m.—2. m.m.	1.11	1.03
0.5 m.m.—1. m.m.	3.57	4.35
Less than		
0.5 m m.	92.97	91.91

A careful examination of the table fails to show any striking pecularities in respect to the chemical composition of this soil. When compared with the results of other analyses it is seen that it occupies an intermediate position between the sandy soils and the clays and is somewhat more closely related to the latter than to the former.

This series of experiments was planned to answer the following questions:

1. What are the fertilizer requirements of the soil of the Experiment Station farm?

2. Do the ordinary farm crops differ in respect to their manurial requirements?

3. Does a liberal supply of humus affect the crop producing power of a soil, and if so how does it act?

In order to answer these questions it was planned to apply the same fertilizer to the same plat year after year and to rotate the crop, for, in this way, the influence of different fertilizers upon the

same crop can be studied each year, and the results with different crops can be compared. The results obtained during the first six years of this experiment are here presented.

RESULTS OBTAINED DURING THE FIRST YEAR OF THE TEST.

In the spring of 1900 a field which had been sown to rye in the fall of 1899, and fertilized at the rate of 400 pounds of complete fertilizer per acre, was selected for this experiment and divided into plats each one-tenth of an acre in size, two rods wide and eight rods long, with an alley four feet wide extending between them. The plats were sown to clover on the 7th of March and the different fertilizers were applied as a top-dressing on the succeeding day.

The following tables show the amount and kind of fertilizer applied, together with the yield of grain and straw per acre:

Plats 13-18	No fertilizer.
Plat 19	40 lbs. sodium nitrate; 40 lbs. Thomas slag; 15 lbs. potassium sulphate; 100 lbs. lime.
Plat 20	Two tons stable manure; 100 lbs. lime.
Plat 21	No fertilizer.
Plat 22	100 lbs. lime.
Plat 23	Ashes from two tons stable manure; nitrogen in the form of sodium nitrate equivalent to the nitrogen originally present in the stable manure.
Plat 24	No fertilizer.
Plat 25	Two tons stable manure.
Plat 26	40 lbs. sodium nitrate; 40 lbs. Thomas slag; 15 lbs. potassium sulphate.
Plat 27	No fertilizer
Plat 28	40 lbs. Thomas slag; 15 lbs. potassium sulphate.
Plat 29	40 lbs. sodium nitrate; 15 lbs. potassium sulphate.
Plat 30	No fertilizer.
Plat 31	40 lbs. sodium nitrate; 40 lbs. Thomas slag.
Plat 32	15 lbs. potassium sulphate.
Plat 33	No fertilizer.
Plat 34	40 lbs. Thomas slag.
Plat 35	40 lbs. sodium nitrate.
Plat 36	No fertilizer.

The fertilizers used in this experiment in 1900 had the following composition:

Sodium nitrate, 15.96 per cent nitrogen.
Potasium sulphate, 35.00 per cent potash.
Thomas slag, 16.73 per cent posphoric acid.

Stable Manure	Water	44.59%	of fresh material
	Ash	14 87 "	" " "
	Lime	2.28 "	" " "
	Potash	1.07 "	" " "
	Nitrogen	.88 "	" " "
	Phos. acid	.57 "	" " "
	Humus	6.16 "	" " "

Table showing the yield of rye from the different plats:

Plat	Fertilizer	Pounds straw per acre	Pounds grain per acre	Ratio of grain to straw
13	No. fert.	2117	1153	1 to 1.83
14	" "	2470	1220	1 to 2.00
15	" "	2318	1182	1 to 1.96
16	" "	2501	1239	1 to 2.01
17	" "	2263	1067	1 to 2.12
18	" "	2385	1215	1 to 1.96
19	N,K_2O,P_2O_5,CaO	3524	2076	1 to 1.69
20	Manure, lime	2762	1578	1 to 1.75
21	No fert.	2064	1186	1 to 1.74
22	Lime	1813	1077	1 to 1.68
23	Ash, N.	3845	2095	1 to 1.83
24	No fert.	2070	1100	1 to 1.88
25	Manure	3587	1913	1 to 1.87
26	N,K_2O,P_2O_5	4317	2463	1 to 1,75
27	No fert.	2583	1297	1 to 1.99
28	$P_2O_5.K_2O$	2739	1411	1 to 1.94
29	N,K_2O	3560	1980	1 to 1.79
30	No fert.	2540	1340	1 to 1.89
31	N,P_2O_5	4153	2267	1 to 1.83
32	K_2O	2678	1402	1 to 1.91
33	No fert.	2600	1330	1 to 1.95
34	P_2O_5	2810	1360	1 to 2.06
35	N.	3716	1914	1 to 1.94
36	No fert.	2380	1220	1 to 1.95

The average yield per acre of the twelve plats which received no fertilizer was 2,357 pounds of straw and 1212 pounds of grain,

while the average of the remaining twelve plats which received different applications of plant food was 3,292 pounds of straw and 1794 pounds of grain, leaving a balance in favor of the fertilizers of 935 pounds of straw and 582 pounds of grain. It may be repeated here that when the rye was sown the entire field in which the plats are situated received an application of 400 pounds of complete fertilizer per acre, and yet in spite of this somewhat liberal application the various top-dressings applied in the spring gave an average increase of over ten bushels of grain per acre.

In the following table the yield of each fertilized plat is compared with the average yield of the two nearest plats which were not fertilized in the spring of 1900. By this method of comparison the minor differences in the natural fertility of the plats are almost wholly eliminated.

		Straw.	Grain.
Plat 19	Excess over average of 18 and 21	1300	876
Plat 20	" " " " 18 and 21	538	378
Plat 22	Decrease from " " 21 and 24	254	66
Plat 23	Excess over " " 21 and 24	1778	952
Plat 25	" " " " 24 and 27	1261	715
Plat 26	" " " " 24 and 27	1991	1265
Plat 28	" " " " 27 and 30	178	93
Plat 29	" " " " 27 and 30	999	662
Plat 31	" " " " 30 and 33	1583	932
Plat 32	" " " " 30 and 33	108	67
Plat 34	" " " " 33 and 36	320	85
Plat 35	" " " " 33 and 36	1226	639

SUMMARY FOR THE FIRST YEAR.

Remembering that the different fertilizers were applied as a top-dressing in the spring the following observations may be made concerning the first year of the test:

1. The table shows that sodium nitrate when applied alone or in combination with potash or phosphoric acid, materially increased the yield of both grain and straw.

2. Thomas slag when used alone, or with potash, increased

the yield but slightly, but when employed with nitrogen was of considerable value.

3. Potassium sulphate when used alone, or combined with either nitrogen or phosphoric acid, was apparently of little benefit.

4. The largest yield was obtained when the three elements, nitrogen, potash, and phosphoric acid were employed, the increase over the average of the two unfertilized plats being 22.5 bushels of grain per acre.

5. The stable manure increased the yield of both grain and straw, acting somewhat more favorably than an application of nitrogen.

6. The ash of stable manure with nitrogen added gave a larger yield than manure alone.

7. Lime when used alone, or in combination with stable manure, or with nitrogen, potash and phosphoric acid, acted injuriously.

RESULTS OBTAINED DURING THE SECOND YEAR OF THE TEST.

The stand of clover upon some of the plats not being satisfactory all of the plats were plowed and prepared for wheat, which was sown October 6, 1900. At the time of sowing the soil was very dry, but rain came on the 7th and 8th of the month, and the wheat promptly came up and made a fairly good growth before winter began.

The same kind and amount of the different fertilizers was applied to the different plats as in the preceding year except that acid phosphate was substituted for Thomas slag, and no more lime was applied to plats 19, 20 and 22. The fertilizers were applied broadcast before the wheat was sown. The acid phosphate employed had the following composition:

Available phosphoric acid	15.74%
Total phosphoric acid	16.30%

The variety of wheat used was the Valley, obtained from the Ohio Experiment Station. It was harvested July 3rd and

threshed from the shock shortly after. All of the plats were again seeded to clover on the 18th of March, resulting in a good stand.

The following tables give the results of the test in 1901:

Table showing the yield of wheat from the different plats:

Plat	Fertilizer	Pounds straw per acre	Pounds grain per acre	Ratio of grain to straw
19	"Complete" fertilizer.	(Lodged severely and not weighed.)		
20	Stable Manure .	4560	1840	1 to 2.47
21	No fert.	1160	1140	1 to 1.11
22	Lime in 1900.	1490	1010	1 to 1.47
23	Ash and N.	3320	1880	1 to 1.76
24	No fert.	1830	1070	1 to 1.71
25	Stable Manure.	4580	1920	1 to 2.38
26	N, K_2O, P_2O_5	3950	1750	1 to 2.25
27	No fert.	1780	1120	1 to 1.58
28	P_2O_5, K_2O	3350	1550	1 to 2.16
29	N, K_2O.	1820	1080	1 to 1.68
30	No fert.	1650	1050	1 to 1.57
31	N, P_2O_5	3550	1550	1 to 2.29
32	K_2O.	1670	1030	1 to 1.62
33	No fert.	1990	1110	1 to 1.79
34	P_2O_5	2610	1390	1 to 1.87
35	N.	1770	930	1 to 1.90
36	No fert.	1250	750	1 to 1.66

The average yield of the six plats which were not fertilized was 1610 pounds of straw and 1040 pounds of grain per acre, while the average of the remaining eleven plats was 2970 pounds of straw and 1448 pounds of grain per acre, leaving a balance in favor of the fertilizers of 1360 pounds of straw and 408 pounds of grain per acre.

In the following table the yield of each fertilized plat is compared with the average yield of the two nearest plats which have not been fertilized, thus bringing out more clearly the influence of the different fertilizers:

Plat			Straw	Grain
20	Excess over	21	3400	700
22	Decrease from average of	21 and 24	5	95
23	Excess over " "	21 and 24	1825	775
25	" " " "	24 and 27	2775	825

Plat						Straw	Grain
26	Excess	over	average	of	24 and 27	2145	655
28	"	"	"	"	27 and 30	1635	465
29	"	"	"	"	27 and 30	105	5 (decrease)
31	"	"	"	"	30 and 33	1730	470
32	Decrease	from	"	"	30 and 33	150	50
34	Excess	over	"	"	33 and 36	990	460
35	"	"	"	"	33 and 36	150	0

OBSERVATIONS CONCERNING THESE RESULTS.

1. Sodium nitrate when used alone slightly increased the amount of straw but did not increase the yield of grain.

2. Acid phosphate when used alone increased the amount of straw nearly one thousand pounds, and the yield of grain slightly more than seven and one-half bushels per acre.

3. Potassium sulphate when used alone decreased both the yield of straw and grain.

4. Sodium nitrate when used with acid phosphate materially increased the yield of straw, and slightly increased the yield of grain, when compared with the plat on which acid phosphate was applied alone.

5. Sodium nitrate when used with potassium sulphate slightly increased the yield of straw, but decreased the yield of grain when compared with the two nearest unfertilized plats.

6. Potassium sulphate when applied with acid phosphate materially increased the yield of straw and slightly increased the yield of grain when compared with the plat to which acid phosphate was applied alone.

7. Sodium nitrate and potassium sulphate when used with acid phosphate gave a larger increase of both grain and straw than when they were individually applied with acid phosphate.

8. A comparison of the preceding observations clearly shows that for wheat phosphoric acid is decidedly deficient in this soil, and that as soon as this deficiency is overcome then there is a lack of both potash and nitrogen.

9. Stable manure gave a larger increase in the yield of grain than any other fertilizer or combination of fertilizers.

10. The ash of stable manure with an equivalent amount of nitrogen applied in the form of sodium nitrate did not give as large an increase as stable manure alone.

11. The plat to which lime was applied alone in 1900 did not give as large a yield as the average of the two adjoining unfertilized plats; when applied in connection with satble manure, however, the yield of straw was larger than on any of the other plats, and undoubtedly the yield of grain would have been larger if the wheat upon this plat had not lodged severely before the heads were filled.

RESULTS OBTAINED DURING THE THIRD YEAR OF THE TEST.

The clover on plats 19 to 36 inclusive was not fertilized as it was desirable to study the after-effect of the previous manurings. Plats 13 to 18 inclusive, which had received no fertilizer since the beginning of the test, received applications of potassium sulphate and the double sulphate of potash and magnesia. The application of these manures was made in order to study the effect of an excessive amount of magnesia in the soil as it has been claimed that too much magnesia in the soil, especially when there is a deficiency of lime, is very deletrious. The potassium sulphate used contained 48.90% potash and the double sulphate of potash and magnesia 24.40% potash and 11.42% magnesia. These fertilizers were applied as a top dressing on April 7th so as to supply 100 pounds of potash per acre to the plats as follows:

Plat	13	Potassium	sulphate.
"	14	"	magnesium sulphate
"	15	"	sulphate
"	16	"	magnesium sulphate
"	17	"	sulphate
"	18	"	magnesium sulphate

The first crop of clover was cut June 23rd and the second crop August 20th. The following table shows the total yield of field cured hay from each plat. The hay when weighed was not cured quite as much as was desirable, but it was dry enough so that it kept well in the mow.

Plat	13	2100	pounds	of	hay	per	acre.	Both crops
"	14	2400	"	"	"	"	"	"
"	15	2600	"	"	"	"	"	"
"	16	2750	"	"	"	"	"	"
"	17	2500	"	"	"	"	"	"
"	18	2800	"	"	"	"	"	"
"	19	6700	"	"	"	"	"	"
"	20	8850	"	"	"	"	"	"
"	21	2050	"	"	"	"	"	"
"	22	1500	"	"	"	"	"	"
"	23	7900	"	"	"	"	"	"
"	24	2100	"	"	"	"	"	"
"	25	9550	"	"	"	"	"	"
"	26	7250	"	"	"	"	"	"
"	27	2850	"	"	"	"	"	"
"	28	5500	"	"	"	"	"	"
"	29	2000	"	"	"	"	"	"
"	30	2650	"	"	"	"	"	"
"	31	7900	"	"	"	"	"	"
"	32	2500	"	"	"	"	"	"
"	33	2200	"	"	"	"	"	"
"	34	5400	"	"	"	"	"	"
"	35	2600	"	"	"	"	"	"

The clover showed no bad effect from the application of the double sulphate of potash and magnesia. The average yield of the three plats to which potassium sulphate was applied was 2400 pounds of hay per acre, while the average yield of the three plats receiving potassium magnesium sulphate was 2650 pounds per acre. It is possible that some crops are more susceptible to an excess of magnesia than others. It is to be observed, also that the average yield of these six plats agrees closely with the yield of plat 32 which has received only potassium fertilizers since the beginning of this experiment.

The following table shows the excess, or decrease, in the yiel of the remaining plats as compared with the average yield of th two nearest unfertilized ones.

		Lbs. Ha per ac
Plat 19	Excess over plat 21	465
" 20	" " " 21	680
" 22	Decrease from average of plats 21 and 24	57
" 23	Excess over " " 21 " 24	582
" 25	" " " " 24 " 27	707
" 26	" " " " 24 " 27	477
" 28	" " " " 27 " 30	275
" 29	Decrease from " " 27 " 30	75
" 31	Excess over " " 30 " 33	547
" 32	" " " " 30 " 33	7
" 34	" " plat 33	320
" 35	" " " 33	40

SUMMARY FOR THE THIRD YEAR.

1. The table shows that former applications of sodium nitrat and potassium sulphate when applied alone did not materially in crease the crop of clover, while former applications of phosphor acid were of decided benefit.

2. Former applications of sodium nitrate and phosphoric aci combined gave a considerably larger excess than phosphoric aci when applied alone, while former applications of a mixture c sodium nitrate and potassium sulphate seem to have acted injur ously.

3. The plat to which phosphoric acid and potash had bee applied in combination did not give as large an increase over th average of the two nearest unfertilized plats as the plat to whic phosphoric acid was applied alone.

4. The plat which received sodium nitrate, potassium sulphat and phosphoric acid did not give as large an increase over th unfertilized plats as the plat to which only sodium nitrate an phosphoric acid had been applied.

5. It is thus seen that in this test former applications of mixture of sodium nitrate and potassium sulphate when use either with or without phosphoric acid acted injuriously.

6. The largest increase over the average of the two nearest unfertilized plats was obtained from the plat to which stable manure had been applied, next in order stands the plat which, in addition to stable manure, had received an application of lime.

7. Comparing the excess yields of plats 23 and 25 to the first of which has been applied ash of stable manure and nitrogen, and to the second only stable manure, it is seen that the stable manure plat gave a considerably larger increase.

8. Plat 22, which received an application of lime in 1900, did not yield as well as the average of the two nearest unfertilized plats; also when the excess yields of plats 19 and 20 are compared with the excess yield of plats 26 and 25, respectively, it is seen that the lime has acted injuriously on this particular soil when used either with a complete fertilizer or with stable manure.

9. The average yield per acre of the five plats, 21, 24, 27, 30 and 33, which have received no fertilizer since the beginning of the experiment, was 2370 pounds of hay per acre, while the average yield of the remaining twelve plats which have been fertilized was 5637 pounds per acre, or more than twice as much as the continually unfertilized plats.

RESULTS OBTAINED DURING THE FOURTH YEAR OF THE TEST.

The clover sod was plowed April 21st, 1903, harrowed thoroughly and planted to corn May 16th, an unnamed yellow dent variety being employed. The fertilizers were applied broadcast immediately before planting and harrowed into the soil. No lime was applied to plats 19 and 20, and only one-half of the usual amount of sodium nitrate was applied, immediately before the corn was planted, to plats 19, 26, 28, 29, 31 and 35, the other half being applied June 15th. No more fertilizer was applied to plats 23 and 25, and acid phosphate was substituted for Thomas slag for all plats receiving phosphoric acid. Owing to the difficulty

of burning the stable manure and applying the ashes, which are very light and easily blown about by the wind, this portion of the experiment was discontinued. Except as noted the same kind and amount of fertilizer was applied to the plats as in the first year of the test.

The season of 1903 was very unfavorable for the growth of corn. The latter part of May, and the months of June and July were excessively wet, while only 2.48 inches of rain fell from the first of August until the 25th of September when the corn was cut. The corn was husked October 10th, and the stalks and the corn in the ear weighed at once.

The following tables show the yield of corn and stalks from various plats:

Plat.	Corn.	Forage.	Plat.	Corn.	Forage.
No. 13	180	335	No. 25	523	650
" 14	197	350	" 26	562	700
" 15	158	300	" 27	198	345
" 16	153	295	" 28	516	620
" 17	174	285	" 29	150	330
" 18	195	290	" 30	182	360
" 19	620	680	" 31	540	700
" 20	770	940	" 32	200	375
" 21	200	380	" 33	193	360
" 22	162	320	" 34	457	575
" 23	441	580	" 35	133	330
" 24	177	365	" 36	150	310

The average yield of plats 13, 15 and 17 which received an application of potassium sulphate in 1902, was 171 pounds of corn and 307 pounds of stalks per plat, while plats 14, 16 and 18 which received potassium magnesium sulphate gave an average yield of 182 pounds of corn and 312 pounds of stalks per plat. As the difference in the yields is so slight it is probable that the presence of the magnesium salt has influenced the results neither one way nor the other. The slight difference in the yields, however, both with corn and clover has been in favor of the double salt.

The following table shows the excess or decrease in the yield of the remaining fertilized plats as compared with the average yield of the two nearest unfertilized ones:

Plat.		Corn.	Stalks.
19	Excess over plat 21	420	300
20	" " " 21	570	560
22	Decrease from the average of plats 21 and 24	26	52
23	Excess over " " " " 21 and 24	253	208
25	" " " " " " 24 and 27	336	295
26	" " " " " " 24 and 27	375	345
28	" " " " " " 27 and 30	326	268
29	Decrease from " " " " 27 and 30	40	22
31	Excess over " " " " 30 and 33	353	340
32	" " " " " " 30 and 33	13	15
34	" " " " " " 33 and 36	286	240
35	Decrease from " " " " 33 and 36	38	5

OBSERVATIONS CONCERNING THE RESULTS SHOWN IN THE PRECEDING TABLE.

1. The plat to which only sodium nitrate was applied did not yield as well as the average of the two nearest unfertilized plats.

2. The application of acid phosphate materially increased the yield of both corn and stover.

3. Potassium sulphate when applied alone increased the yield but slightly when compared with the average of the two nearest unfertilized plats.

4. Plats 28 and 31, to the former of which potash and phosphoric acid have been applied, and to the latter nitrogen and phosphoric acid, yielded considerably more than the plat which has received only phosphoric acid.

5. Plat 29, fertilized with sodium nitrate and potassium sulphate, did not yield as well as the average of the two nearest unfertilized plats.

6. The plat which received all three constituents gave a larger increase than where sodium nitrate or potassium sulphate have been individually applied with acid phosphate.

7. Comparing the yields of plats 23 and 25, it is seen that the plat which has received two applications of stable manure gave a larger increase than the plat which has received the ash of stable manure and sodium nitrate.

8. Plat 22 which has received two small applications of lime did not yield as well as the average of the two nearest unfertilized plats.

9. Comparing the excess yields of plats 19 and 26 which have been uniformily fertilized with nitrogen, potash and phosphoric acid, with the addition of lime to plat 19, in 1900, it is seen that the limed plat gave a larger yield of corn with a smaller growth of stalks than the other plat.

10. The largest excess yield was obtained from plat 20, which in addition to three applications of stable manure was limed in 1900.

FIFTH YEAR OF THE TEST.

After the corn was removed in the autumn of 1903 rye was drilled upon all of the plats as a cover crop, no fertilizer being used. The small amount of growth which resulted was plowed under in the spring of 1904, and the land prepared for cowpeas which were sown June 9th, the black variety being employed.

The fertilizers were applied shortly before the seed was sown and thoroughly harrowed into the soil. The same kind and amount of fertilizer was applied as was the case the first year of the test with the exception that no more lime was applied to plats 19, 20 and 22; no further application was made to plat 23; and acid phosphate was substituted in all cases for Thomas slag.

The plats were cut for hay October 6th. The vines were allowed to cure for about one week and were then weighed. The follow-

ing table shows the weight of the hay obtained from the different plats:

	Pounds Hay.		Pounds Hay.
Plats 13 to 18 inclusive...	800	" 27	220
Plat 19	695	" 28	440
" 20	675	" 29	230
" 21	125	" 30	210
" 22	120	" 31	515
" 23	275	" 32	195
" 24	135	" 33	245
" 25	610	" 34	365
" 26	630	" 35	250

The following table shows the increase or the decrease in the yields of the fertilized plats when compared with the average of the two nearest plats which have remained unfertilized:

Plat 19	Excess over 21	570 lbs.
" 20	" " 21	550 "
" 22	Decrease from the average yield of 21 and 24	10 "
" 23	Excess over " " " " 21 and 24	145 "
" 25	" " " " " " 24 and 27	433 "
" 26	" " " " " " 24 and 27	453 "
" 28	" " " " " " 27 and 30	225 "
" 29	" " " " " " 27 and 30	5 "
" 31	" " " " " " 30 and 33	288 "
" 32	Decrease from " " " " 30 and 33	32 "
" 34	Excess over 33	120 "
" 35	" " 33	5 "

OBSERVATIONS CONCERNING THESE RESULTS.

1. Plat 35 to which sodium nitrate was applied yielded practically the same as plat 33 to which no fertilizer has been applied since the beginning of the test.

2. The application of acid phosphate to plat 34 materially increased the yield.

3. Plat 32 to which potassium sulphate was applied gave a

smaller yield than the average of the two nearest unfertilized plats.

4. In the case of plats 28 and 31 to the former of which potassium sulphate, and to the latter sodium nitrate was used in connection with acid phosphate, the application of these salts in connection with acid phosphate practically doubled the excess yields as compared with the plat to which acid phosphate was applied alone.

5. Plat 29 fertilized with potassium sulphate and sodium nitrate yielded practically the same as the average of the two unfertilized plats.

6. Plat 26, to which sodium nitrate, potassium sulphate and acid phosphate were applied, gave a slightly larger excess than the plat to which stable manure was applied. This plat also gave a much larger excess than plats 28 and 31, to which sodium nitrate and potassium sulphate were individually applied with acid phosphate.

7. Plat 23 to which the ash of stable manure and nitrogen were applied during the first two years of the test still shows the influence of this fertilization.

8. Former applications of lime to plat 22 seem to have exerted a deleterious influence.

9. Comparing the excess yields of plats 19 and 26 it is seen that the plat which has received one application of lime in addition to other fertilizers gave a larger excess yield than the plat to which no lime has been applied. This plat also gave the largest actual, as well as the largest excess yield, of any of the plats, closely followed by plat 20, which has been continuously fertilized with stable manure, except when the land was in clover, and has received in addition one application of lime.

SIXTH YEAR OF THE TEST.

The plats were plowed in the spring and prepared for corn, which was planted May 23rd, the Ensilage Red Cob variety being used. The rows were three and one-half feet apart, and the hills

two feet apart in the row, and the corn planter was adjusted so as to plant two kernels in a hill.

The fertilizers were applied broadcast a few days before the corn was planted and harrowed into the soil. No lime was applied to plats 19, 20 and 22; no more fertilizer was applied to plat 23; and acid phosphate was used instead of Thomas slag. Except as noted the same kind and amount of fertilizer was applied to the different plats as in the first year of the test.

The corn on these plats was used for ensilage. It was cut and shocked on the 23rd and 25th of September, and photographed and weighed on the 26th. When cut the kernels on the plats which have been fertilized were mostly glazed, while the grain on the unfertilized plats was mostly in the milk.

The following table gives the weight of the crops from the different plats.

	Pounds		Pounds
Plat 18	930	" 27	1250
" 19	2770	" 28	1610
" 20	3470	" 29	1500
" 21	1120	" 30	1090
" 22	980	" 31	1890
" 23	1530	" 32	1180
" 24	1210	" 33	870
" 25	3480	" 34	1410
" 26	2900	" 35	1020

The following table shows the increase or the decrease in the yields of the fertilized plats when compared with the average of the two nearest plats which have been unfertilized:

Plat 19	Excess over the average of plats	18 and 21	1745 lbs.
" 20	" " " " " "	18 and 21	2445 "
" 22	Decrease from the average of plats	21 and 24	185 "
" 23	Excess over " " " "	21 and 24	365 "
" 25	" " " " " "	24 and 27	2250 "
" 26	" " " " " "	24 and 27	1670 "
" 28	" " " " " "	27 and 30	440 "
" 29	" " " " " "	27 and 30	330 "
" 31	" " " " " "	30 and 33	910 "
" 32	" " " " " "	30 and 33	200 "
" 34	" " plat 33		540 "
" 35	" " " 33		150 "

PLATE 1

PLAT 19
Phosphoric Acid, Nitrogen, Potash, Lime.

PLAT 18
No fertilizer

PLAT 21
No fertilizer.

PLAT 20
Stable Manure, Lime.

PLATE 2

PLAT 23
Ash of stable manure and nitrogen.

PLAT 22
Lime.

PLAT 25
Stable manure.

PLAT 24
No fertilizer.

PLATE 4

PLAT 31
Phosdhoric acid, Nitrogen.

PLAT 30
No fertilizer.

PLAT 33
No fertilizer.

PLAT 32
Potash.

PLATE 5

PLAT 35
Nitrogen

PLAT 34
Phosphoric acid.

PLATE 6

PLAT 20
Stable manure.

PLAT 21
No fertilizer.

OBSERVATIONS CONCERNING THESE RESULTS.

1. Somewhat in contrast with the results obtained in former years sodium nitrate and potassium sulphate when applied alone were of some benefit. The acid phosphate, however, gave an increase more than three times as large as that derived from the use of sodium nitrate and more than two and one-half times as large as the increase from the use of potassium sulphate.

2. Plat 31, which received a mixture of sodium nitrate and acid phosphate gave a larger increase in the yield than the total increase on the three plats, 32, 34 and 35, which were fertilized with potassium sulphate, acid phosphate and sodium nitrate. This agrees fully with the result obtained with corn during the fourth year of the test.

3. The application of the mixture of sodium nitrate and potassium sulphate to plat 29 produced about the same increase as the total increase on the two plats to which they were applied alone.

4. Plat 28, which received a mixture of potassium sulphate and acid phosphate did not yield as large an increase as plat 34, to which only acid phosphate was applied.

5. Plat 26, which received the three constituents, nitrogen, potash and phosphoric acid, gave a much larger excess than was produced by a mixture of any two constituents.

6. The largest yield and the largest excess yields were produced by plats 20 and 24, which have been fertilized with stable manure. The actual yield of the two plats are practically identical, but plat 20, which has been limed, gave a slightly larger excess.

7. Plat 23, which received the ash of stable manure, still shows the beneficial effect of the ash constituents.

8. As in former years, the yield of the limed plat has failed to come up to the average of the unfertilized plats.

SUMMARY AND CONCLUSIONS FOR THE SIX YEARS.

For the purpose of comparing the results obtained during the different years the following table has been prepared, showing the excess yields for the six years under consideration:

SUMMARY OF "EXCESS YIELDS" STATED IN POUNDS PER ACRE.

	Rye 1900		Wheat 1901		Clover 1902	Corn 1903		Cow-peas 1904	Corn 1905
Plat	Straw	Grain	Straw	Grain	Hay	Corn	Stover	Hay	Entire Crop
19	1300	876			4650	4200	3000	5700	17450
20	538	378	3400	700	6800	5700	5600	5500	24450
22	−254	−66	−5	−95	−575	−260	−520	−100	−1850
23	1778	952	1825	775	5825	2530	2080	1450	3650
25	1261	715	2775	825	7075	3360	2950	4330	22500
26	1991	1265	2145	665	4775	3750	3450	4530	16700
28	178	93	1635	465	2750	3260	2680	2250	4400
29	999	662	105	—5	−750	−400	−220	50	3300
31	1583	932	1730	470	5475	3530	3400	2880	9100
32	108	67	−150	−50	75	130	150	−320	2000
34	320	85	990	460	3200	2860	2400	1200	5400
35	1226	639	150	0	400	−380	−50	50	1500

1. *NITROGEN.* The only time that sodium nitrate has been of any particular benefit, when applied alone, was when it was used as a top-dressing in the spring on rye. When used in connection with phosphoric acid it has uniformly increased the yields when compared with the plat to which phosphoric acid has been applied alone. When used in connection with potassium sulphate the yields have been unsatisfactory, except in one instance when the mixture was applied to rye as a top-dressing in the spring, and then the beneficial effect was probably due to the presence of the readily soluble sodium nitrate.

2. *POTASH.* When potassium sulphate has been used alone the yields have been either only slightly larger or actually smaller than the average of the two nearest unfertiliezd plats. When

used with phosphoric acid the excess yields have been, in general, only slightly larger than when phosphoric acid has been used alone.

3. *PHOSPHORIC ACID.* When applied alone Thomas slag and acid phosphate have uniformly increased the yields. When a mixture containing the three constituents, nitrogen, potash and phosphoric acid, has been applied the excess yields have been larger, with a single exception, than when any one or any two constituents have been employed.

4. *POTASH AND NITROGEN.*—The mixture containing potash and nitrogen has given poorer results than the mixture containing either potash and phosphoric acid, or nitrogen and phosphoric acid, except in the first year of the test when the fertilizer was applied in the spring as a top-dressing. This indicates *that in this soil the stock of available phosphoric acid is so low that the deficiency of this constituent must be supplied before either nitrogen or potash can be of any particular value.*

5. *NITROGEN AND PHOSPHORIC ACID.*—In all cases the mixture containing nitrogen and phosphoric acid gave larger excess yields than did a mixture containing potash and phosphoric acid, or, in other words, *after the deficiency of phosphoric acid is supplied plants feel the lack of nitrogen in this soil more acutely than they do of potash.*

6. *STABLE MANURE.*—Stable manure has increased the yields materially and uniformly. Plat 25 which received two applications of stable manure during the first and second years of the test yielded almost as much corn in 1903 as plat 26, which had received up to that time three applications of complete fertilizer. During the first year when it was applied as a top-dressing the excess yield was somewhat smaller than that obtained from the complete fertilizer plat. During the second year the excess yield was larger, and during the third year when no fertilizer was applied to any of the plats, the yield of clover hay was almost double that obtained from the plats to which the complete fertilizer had been

applied. During the last two years the excess yields were in one case smaller and in the other case larger than the excess yields of plat 26 which has received a mixture containing nitrogen, potash and phosphoric acid.

7. *LIME.*—The two applications of lime applied to plat 22 have reduced the yields as compared with the averages of the two nearest unfertilized plats. Comparing the excess yields of plats 19 and 26 it is seen that the lime applied to plat 19 during the first year of the test seems to have reduced the yield during the first three years and to have acted somewhat favorably during the last three years. During the first three years of the test plats 20 and 25 received the same amount of stable manure. The lime applied to plat 20 seems to have favored the growth of the crop during the second year as the wheat grew so luxuriently that it lodged badly. In 1902 the excess yield of clover hay was slightly lower than in the case of plat 25, and the yields during succeeding years are not strictly comparable as plat 20 received a dressing of stable manure in 1903 which was not given plat 25. So in general we may say that with lime the results on this soil have been totally unsatisfactory.

8. *HUMUS.*—During the first two years of the test plat 25 received two applications of stable manure and plat 23 two applications of the ash of stable manure and an equivalent amount of nitrogen in the form of sodium nitrate. Neither of these two plats received any further application of fertilizer for the next two years. We may compare, therefore, their yields for the first four years of the test.

Except during the first year of the test, the plat which has received stable manure has produced a larger excess yield than the plat receiving the ash of stable manure and nitrogen. Whether this favorable effect of the stable manure has been due to the gradual liberation of plant food during the growing season; to the greater amount of moisture which the soil is capable of holding and supplying to the crop; or to other factors, is a matter which has not been answered definitely. It is entirely probable

that several factors may have aided in producing the larger yields of the stable manure plat. It is worthy of notice that although plat 23 has remained unfertilized since 1901 yet it has continued to give larger excess yields than the plats continuously fertilized with sodium nitrate, potassium sulphate, or with a mixture of these two salts.

9. *THE FERTILIZER REQUIREMENTS OF DIFFERENT CROPS.*—From the results obtained in this test it may be stated that, within the limits of the crops grown, a fertilizer which gives good results with one crop will give good results with another crop grown upon the same or similar soil. For example, the application of a fertilizer containing phosphoric acid gave good results with rye, wheat, clover, cowpeas, and corn. Similarly stable manure gave good results in all cases. The table shows, however, that there are some minor exceptions to this general rule. For if the yield of cowpeas and corn are compared during the last two years of the test it is seen that the cowpeas which received a mixture of sodium nitrate, acid phosphate, and potassium sulphate. (plats 19 and 26) gave a larger excess yield than when supplied with stable manure (plats 20 and 25), while in the case of corn in 1905 the exact opposite is true. Also in 1903 the corn on plat 20 fertilized with stable manure gave a larger excess than on plat 19 dressed with commercial fertilizer, and the same probably would have been true in the case of plats 25 and 26 had not the stable manure plat been injured and the yield reduced by a very heavy thunder shower which caused a stream of water to cut a channel diagonally across this plat. From this evidence we may conclude *that corn responds more favorably to a dressing of stable manure than it does to an application of commercial fertilizer, while with cowpeas the exact opposite is true.* This conclusion, also, is in entire agreement with common farm practice in which stable manure is generally used for corn, and commercial fertilizer for cowpeas. It may be observed here that although the roots of these cowpeas were well supplied with nodules yet the plats receiving all three fertilizing constituents (plats 19 and 26) gave larger excesses than when any one or any two constituents were supplied.

Also that a mixture of sodium nitrate and acid phosphate gave slightly better results than a mixture of potassium sulphate and acid phosphate, although cowpeas are supposed to be able to obtain their supplies of nitrogen from the free nitrogen of the air when provided with root tubercles.

PRACTICAL SUGGESTIONS. This experiment shows that this soil is very deficient in available phosphoric acid, and that as soon as this deficiency is supplied then there is a lack of nitrogen and to a less extent of potash also.

When commercial fertilizers are relied upon entirely to maintain a high degree of crop production a fertilizer containing all three constituents, nitrogen, potash, and phosphoric acid will give better results than a fertilizer containing only one or two of these constituents. Aside from the fact that a fertilizer should be especially rich in phosphoric acid these experiments do not indicate the exact proportion in which nitrogen, potash and phosphoric acid should enter into a fertilizer for best results. This will be made the subject of further study.

If leguminous crops are raised and either plowed under or fed on the farm and the resulting manure carefully saved and applied to the soil it is very probable that in practice it will be necessary to purchase only phosphoric acid in order to increase the productiveness of soils of this type and to maintain them in a condition of high fertility.

Stable manure has demonstrated again its great value as a restorer of fertility to a poor worn out soil. More manure should be produced on West Virginia farms, it should be protected from leaching and heating more carefully, and should be applied to the soil more systematically and more intelligently than is the case at the present time.